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SITE Technology Capsule

In Situ Electrokinetic Extraction System

Abstract

As part of the Superfund Innovative Technology Evaluation (SITE) program, the U.S. Environmental Protection Agency (EPA) demonstrated the In Situ Electrokinetic Extraction (ISEE) system at the U.S. Department of Energy (DOE) Sandia National Laboratories (SNL) Chemical Waste Landfill site in Albuquerque, New Mexico. This demonstration was funded by DOE's Office of Science and Technology through the Subsurface Contamination Focus Area. The ISEE system treated chromate-contaminated soil at the Unlined Chromic Acid Pit (UCAP) of the SNL Chemical Waste Landfill site.

The SITE demonstration results show that the ISEE system removed hexavalent chromium in the form of chromate from soil under unsaturated conditions. At SNL's preferred operating conditions, (1) approximately 200 grams (g) of hexavalent chromium were removed during about 700 hours of system operation, (2) the overall removal efficiency for the system was approximately 0.14 g of hexavalent chromium per kilowatt hour (kWh), and (3) the average removal rate for the entire system was approximately 0.29 g/ hour.

Potential sites for appropriate application of this technology include Superfund and other hazardous waste sites where soils are contaminated with hexavalent chromium under unsaturated conditions. Economic data indicate that soil remediation costs are very high, perhaps because the system demonstrated at UCAP requires significant improvements.

Introduction

The SITE program was established in 1986 to accelerate the development, demonstration, and use of innovative new technologies that offer permanent cleanup alternatives for hazardous wastes. One component of the SITE program is the demonstration program, under which engineering, performance, and cost data are developed for innovative treatment technologies. Data developed under the SITE demonstration program enables potential users to evaluate each technology's applicability to specific waste sites.

The SITE demonstration of the SNL ISEE system was conducted at the UCAP within the Chemical Waste Landfill site at Technical Area III. The system was evaluated from May 15 to November 24, 1996, to determine its effectiveness for treating unsaturated soil contaminated with hexavalent chromium.

This technology capsule was developed by EPA's Office of Research and Development in Cincinnati, Ohio, to announce key findings of the ISEE SITE demonstration, which is fully documented in two separate reports: the innovative technology evaluation report (ITER) and the technology evaluation report. These reports can be obtained by contacting Mr. Randy Parker (see "Source of Further Information" below).

SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

This capsule summarizes the following information:

- Technology description
- Technology applicability
- Technology limitations
- SITE demonstration overview
- Treatment residual
- Site preparation requirements
- Demonstration results
- Operating problems
- Comparison to Superfund feasibility evaluation criteria
- Estimated treatment costs
- Technology status
- Source of further information

Technology Description

The ISEE system was developed by SNL to remove hexavalent chromium from unsaturated soil. The ISEE system used for the demonstration was housed in two buildings: a control trailer and a temporary structure. The control trailer contained the control panels, the power supply, and the data logging system. The temporary structure protected the electrokinetic technology equipment and personnel and maintained the operational exclusion zone required during ISEE system operation.

The technology involves the in situ application of direct current to soil, which results in dissolved chromate ions migrating through water in soil pores to the anode, a phenomenon known as electromigration. In addition to electromigration cathode, a bulk flow of pore water occurs toward the cathode, a phenomenon known as electroosmosis. Chromate ions are extracted in the anode effluent.

The SNL ISEE system consists of the following: an electrode system, a vacuum control system, a water control system, a power supply, a monitoring system, and ancillary equipment. Figure 1 shows the ISEE system's main components. Figure 2 shows the electrode layout of the ISEE system used during the SITE demonstration. The system consisted of an anode row oriented east to west and four rows of cathodes parallel to the anode row, two rows north and two rows south of the anode row. Two types of cathodes were used during the SITE demonstration: cathodes similar to the anodes, which will be referred to as "cathodes," and simple design cathodes, which will be referred to as "cold finger cathodes" (identified as "CF" if they are standalone or "CFC" if they are adjacent to cathode casings). The treatment zone was determined by the active portion of these electrodes and extended from 8 to 14 feet bgs.

The innovative feature of the ISEE system is that lysimeter technology is used in the construction of the anodes and cathodes to hydraulically and electrically create a continuum between the electrolyte and the pore water. The electrode fluid is held inside the electrode by an applied vacuum, keeping the fluid from saturating soil. This feature allowed the removal of chromate from unsaturated soil

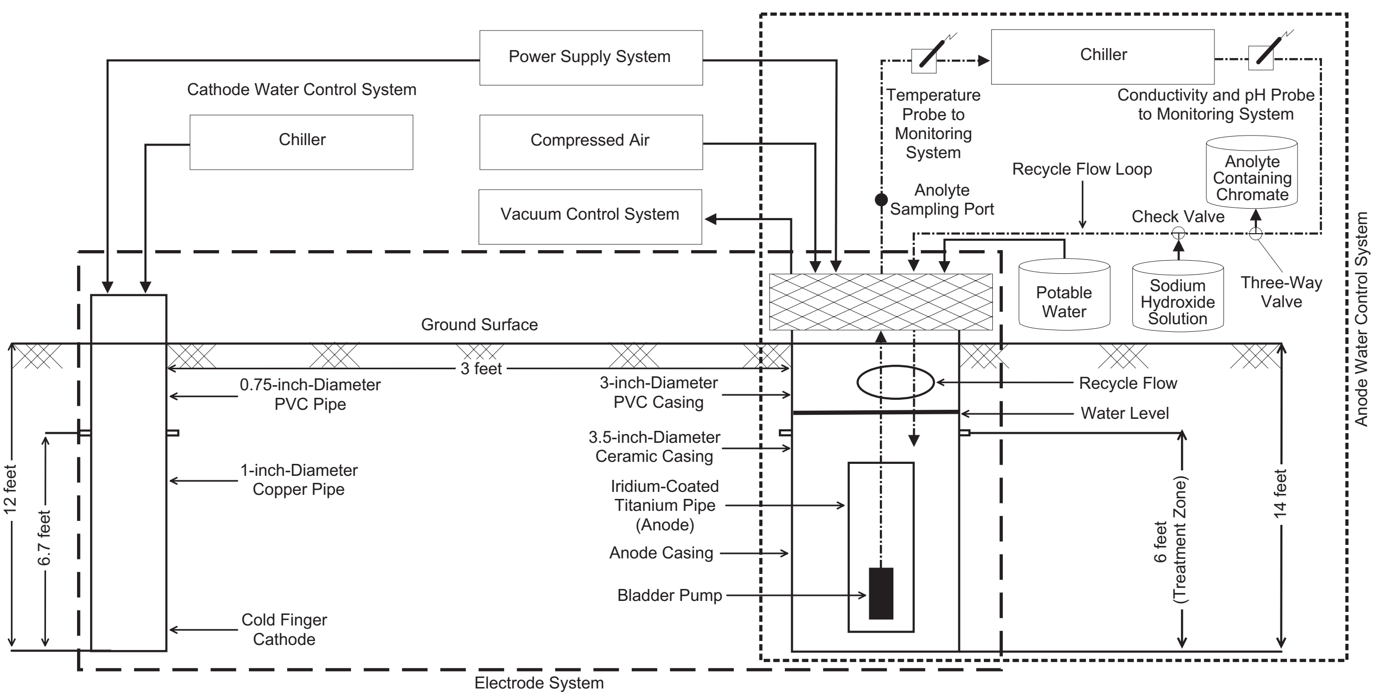

Figure 1. ISEE system schematic diagram.

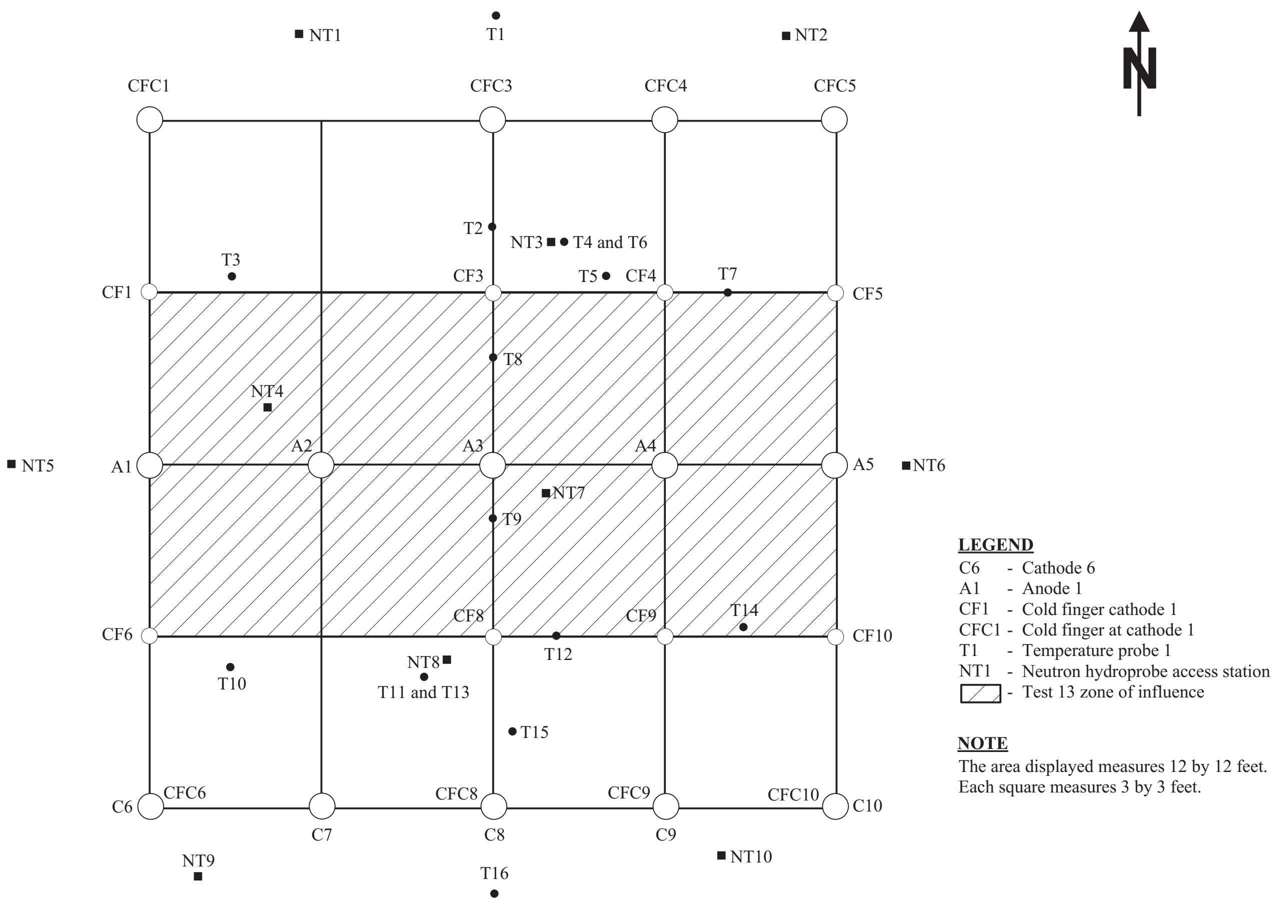

Figure 2. Test area electrode layout.

during the demonstration without significantly altering the soil moisture content. The vacuum control system maintains the vacuum in the anode electrode, which creates the pressure gradient between the anode's porous ceramic casing and the surrounding soil necessary to hydraulically control water movement between the anode casing and the soil. Hydrogen gas, which is produced by electrolysis reactions resulting from direct current application, was purged from the cathode casing to eliminate the danger of explosion.

The water control system consists of water circulation and pH control systems. The anode water circulation system mixes the anolyte in the electrode, removes and samples anolyte, monitors the chemical condition of the anolyte, and maintains the anolyte temperature at about 12 ^{o}C. Circulation is maintained in a recycle flow loop by a bladder pump. Because the bladder pump is contained in the electrode casing, under subatmospheric conditions, an additional vacuum source is necessary for its operation. The cold finger cathode water control system consists of a chiller that cools water pumped to the cathodes and has no recirculation system. The pH control system maintains the pH of the anolyte at about 9 using a 10 percent sodium hydroxide solution.

The power supply energizes the electrodes. The demonstration system consisted of four 10-kilowatt (kW) power supply units. Each unit was operated independently under constant voltage conditions. The current applied to each electrode was monitored and limited to 15 amperes (A).

The monitoring system records water control system information such as anode casing water level, recycle flow rate, influent and effluent rates, recycle flow temperature, conductivity, and pH. The monitoring system also records air purge rates, the vacuum in the anodes, and ancillary equipment information such as soil temperature and voltage profiles of subsurface soil. The monitoring system can shut down the entire ISEE system if operational parameters are not within established ranges.

Technology Applicability

The ISEE technology developed by SNL is applicable for treating unsaturated soil contaminated with hexavalent chromium. According to SNL, this technology can be modified to treat saturated contaminated soil and to remove contaminants dissolved in the pore water besides chromate. Because other anions will compete with the targeted contaminant ions to be removed, it is necessary to determine the electrical conductivity of the soil pore water and the target ion concentration to determine the applicability of the technology.

Technology Limitations

Prior to implementing electrokinetic remediation at a specific site, field and laboratory screening tests should be conducted to determine if the site is amenable to this technology.

Field conductivity surveys are necessary to determine the soil's electrical conductivity. Also, buried metallic objects and utility lines could short-circuit the current path, thereby influencing the voltage gradient and affecting the contaminant extraction rate. Electromagnetic surveys should be conducted to determine the presence of buried metallic objects.

In addition, if volatile organic compounds (VOC) are present in soil at the site undergoing electrokinetic treatment, the VOCs will likely be stripped from the soil to significantly increase the soil vapor VOC concentrations that could result in significant VOC migration from the treatment area, if soil temperature exceeds 50°C. Special measures therefore need to be taken to contain and control VOC emissions.

SITE Demonstration Overview

The ISEE technology SITE demonstration was initiated on May 15, 1996, and was terminated on November 24, 1996. During this period, the system operated for a total of about 2,800 hours. The test areas ranged from 36 to 72 square feet, and contaminated soil at 8 to 14 feet bgs was treated. Predemonstration soil samples collected within the test areas contained hexavalent chromium at concentrations ranging from below the detection limit of 0.4 milligram per kilogram (mg/kg) to 6,890 mg/kg and total chromium at concentrations ranging from 7.7 to 26,800 mg/kg.

Evaluation of hexavalent chromium removal from soil by the ISEE system was the primary project objective because the ISEE system is primarily designed to remove hexavalent chromium. To accomplish this objective, SNL collected and analyzed anolyte samples for hexavalent chromium at the field laboratory throughout the demonstration period. An independent check of field analytical data was provided by EPA through split sample analysis at an off-site laboratory. Field analytical data were therefore deemed adequate to estimate the amount of hexavalent chromium removed from soil by the ISEE system.

Predemonstration and postdemonstration soil samples collected by EPA were analyzed for hexavalent chromium to verify the hexavalent chromium removal estimate based on anolyte sample analysis.

The secondary objectives of the technology demonstration were to determine whether treated soil meets the toxicity characteristic leaching procedure (TCLP) regulatory criterion for chromium and to evaluate the ISEE system's ability to remove trivalent chromium from site soil.

To conduct the demonstration, SNL was required to meet the conditions of the New Mexico Environmental Department's Resource Conservation and Recovery Act (RCRA) Research, Development, and Demonstration permit for the ISEE system. Predemonstration testing results indicated that some of the soil in the demonstration area is hazardous (EPA waste code D007) because chromium concentrations exceeded the TCLP criterion for chromium. Therefore, the permit required that SNL perform postdemonstration TCLP testing to determine the impact of the ISEE system on soil known to be contaminated. SNL therefore collected a large number of treated soil samples for total chromium analysis after extraction using TCLP.

Because incidental removal of trivalent chromium will likely be accomplished by the ISEE system, evaluation of trivalent chromium removal was a secondary project objective of this project. To accomplish this objective, the predemonstration and postdemonstration soil samples collected for hexavalent chromium analysis were also analyzed for total chromium so that the trivalent chromium concentrations could be calculated as the difference between the total and hexavalent chromium concentrations.

During the SITE demonstration, 13 tests were performed during six phases. The test areas ranged from 36 to 72 square feet, and contaminated soil from 8 to 14 feet bgs was treated. The first 12 tests were conducted so that SNL could determine the preferred operating conditions for test 13 and to facilitate the migration of hexavalent chromium toward the central portion of the test area. Test 13 consisted of system performance testing under SNL's preferred operating conditions for the SITE demonstration. Table 1 summarizes key conditions of the 13 tests.

Treatment Residual

The ISEE system treatment residual consists of anolyte. This effluent contains hexavalent chromium extracted from the soil in the form of chromate solution. The ISEE system does not have the capability to treat this waste stream; therefore, this treatment residual should be characterized and disposed of as hazardous waste.

Table 1. Test Conditions for SNL ISEE System SITE Demonstration

	Test Area	Test No.	Phase	Cathodes Used	Average Current (A)	Average Power (kW)	Analyte Extraction Rate (L/hour)	Test Duration (hour)
1	South Side (A1-A5 to C6-C10)	1	A1, A2, A3, A4, and A5	C6, C7, C8, C9, and C10	19.45	1.3	0.44	106
		2	A1, A3, A4, and A5	C6, C7, C8, C9, and C10	21.09	1.68	0.87	368
		3	A1, A3, A4, and A5	C6, C8, C9, and C10	20.08	1.77	0.879	283
		4	A1, A3, A4, and A5	C6, C8, C9, and C10	34.25	4.65	2.026	244
		5	A1, A3, A4, and A5	C6, C8, C9, and C10	42.15	5.76	3.54	34
		6	A1, A3, A4, and A5	C6, C8, C9, and C10	41.07	4.56	3.957	181
2	North Side (A1-A5 to CFC1-CFC5)	7	A1, A3, A4, and A5	CFC1, CFC3, CFC4, and CFC5	29.27	4.14	3.404	75
		8	A1, A3, A4, and A5	CFC1, CFC3, CFC4, and CFC5	20.94	1.9	0.376	89
		9	A1, A3, A4, and A5	CFC1, CFC3, CFC4, and CFC5	20.79	1.87	0.723	333
3	Southern Half of North Side (A1-A5 to CF1-CF5)	10	A1, A3, A4, and A5	CF1, CF3, CF4, and CF5	30.31	2.7	0.51	176
4	South Side (A1-A5 to CFC6-CFC10)	11	A1, A3, A4, and A5	CFC6, C8, CFC9, and CFC10	33.49	2.38	0.5	20
5	Northern Half of South Side (A1-A5 to CF6-CF10)	12	A1, A3, A4, and A5	CF6, CF8, CF9, and CF10	39.31	2.86	0.848	111
6	Central Portion (CF1-CF5 to CF6-CF10)	13	A1, A3, A4, and A5	CF1, CF3 through CF6, and CF8 through CF10	35.92	2.1	0.662	707

Site Preparation Requirements

This section describes site preparation requirements for the ISEE technology. Some of these requirements may apply to situations in which the ISEE system is used to remediate contaminated soil. During the demonstration, in addition to the test area, an additional 8,800 square feet were necessary to accommodate the control trailer, water tanks, and supply storage. Based on the design of the ISEE system, which can transmit system information off site, no personnel are required to be present on site for system operation. The system is equipped with a CR7 data-logger that monitors system parameters and can shut down the system (such as by cutting off power to the electrodes and terminating the water supply). The data-logger consequently sends a signal to the system operator identifying the problem. Technical service personnel should be available on an as-need basis to remediate any problems. According to the developer, maintenance and routine sampling and analysis requirements for a full-scale system should require the on-site presence of a technician for 8 hours a week.

The ISEE system demonstrated at UCAP was powered by four 10-kW power supply units. The units were capable of operating independently or in parallel. When connected in parallel, the maximum output was 64 A at 600 volts of direct current. According to the developer, a three-phase, 230-volt, 150-kW power supply is necessary to operate a full-scale system.

Potable and decontamination water are also necessary to operate the system. The monitoring system requires connection to a telephone line or cellular telephone to download data to an off-site computer and to transmit a signal indicating that the system has shut down to maintenance personnel.

A temporary structure may be required to protect the ISEE system and personnel from the weather and also to provide an exclusion zone during system operation. The data-logger, control panels, and other analytical equipment can be housed in a trailer. If the ISEE system is used outdoors in a cold climate, provisions should be made for insulating the exposed portions of the water control system to prevent freezing.

Demonstration Results

The following sections summarize results of the ISEE system SITE demonstration according to the primary and two secondary project objectives.

Removal of Hexavalent Chromium

The primary objective of the ISEE system demonstration was to estimate the amount of hexavalent chromium removed from soil by the ISEE system. The mass of hexavalent chromium removed was to be determined from the amount of hexavalent chromium extracted in the anolyte during the demonstration.

As mentioned before, 13 tests were performed in six phases during the demonstration. The first 12 tests, performed between May 15 and October 18, 1996, were used by SNL to determine preferred operating conditions of the system. Test 13 was performed between October 21 and November 24, 1996, to determine system performance and the operating costs. Test 13 was conducted in the central portion of the demonstration area, which measured 12 by 6 feet. The system was operated for 707 hours in this configuration. Table 2 summarizes ISEE system performance results during the 13 tests performed.

The total mass of hexavalent chromium extracted by the ISEE system should have been verified by calculating the difference between hexavalent chromium mass in treated soil before and after the demonstration. However, soil results for hexavalent chromium exhibited a high spatial variability resulting from (1) the nonhomogeneous distribution of chromate concentrations in soil before the demonstration and (2) the fact that the demonstration was terminated before chromate removal was completed. In addition, limited data appear to indicate that contaminants had likely migrated from areas outside of and near the treatment area. Thus, a determination of the mass of hexavalent chromium removed based on soil sampling results was not possible.

Hexavalent chromium soil sampling results are as follows: (1) 51 predemonstration soil samples contained hexavalent chromium-concentrations from below the detection limit of

Table 2. ISEE System Hexavalent Chromium Removal Results

Test No.	Test Duration (hour)	Hexavalent Chromium Mass Removed (g)	Hexavalent Chromium Removal Rate (g/hour)	Hexavalent Chromium Removal Efficiency (g/kWh)
1	106	7.84	0.074	0.057
2	368	35.7	0.097	0.058
3	283	22.5	0.079	0.046
4	244	56.0	0.230	0.049
5	34	11.5	0.338	0.058
6	181	38.2	0.211	0.047
7	75	11.1	0.149	0.036
8	89	9.01	0.101	0.053
9	333	59.0	0.176	0.094
10	176	36.0	0.204	0.075
11	20	4.71	0.236	0.094
12	111	25.4	0.229	0.081
13	707	204	0.288	0.136

0.4 mg/kg to 6,890 mg/kg; and (2) 84 postdemonstration soil samples contained hexavalent chromium concentrations from below the detection limit of 0.4 mg/kg to 4,730 mg/kg. Of the 48 locations sampled both before and after the demonstration, 21 locations contained postdemonstration hexavalent chromium in concentrations that exceeded predemonstration concentrations. As stated earlier, soil analytical results could not be used to verify the estimated mass of hexavalent chromium removed based on anolyte results.

Compliance with TCLP Regulatory Criterion for Chromium

Table 3 presents TCLP results for chromium for soil samples collected before and after the demonstration from the treatment zone from approximately 8 to 14 feet bgs. Of the 43 predemonstration soil samples analyzed by TCLP, 18 exceeded the TCLP limit of 5 milligrams per liter (mg/L) of total chromium at concentrations ranging from 5.6 to 103 mg/L, with a median concentration of 15.4 mg/L.

Table 3. ISEE System TCLP Chromium Results

Sampling Location No.	Sampling Depth: 8 to 10 feet bgs		10 to 12 feet bgs		12 to 14 feet bgs	
	Predemonstration (mg/L)	Postdemonstration (mg/L)	Predemonstration (mg/L)	Postdemonstration (mg/L)	Predemonstration (mg/L)	Postdemonstration (mg/L)
A1	0.64	--	**20.8**	**19.7**	0.52	--
A2	< 0.5	--	3	--	1.8	**14**
A3	< 3.3	--	**17.8**	**9.4**	**20.8**	--
A5	2.5	--	**103**	--	**19.5**	--
C1[a]	< 1	--	< 0.5	--	< 0.5	--
C2[a]	< 1	--	--	--	--	--
C3[a]	< 1	--	< 0.5	--	< 0.5	--
C4[a]	--	0.078	--	0.017	--	**8.9**
C5[a]	< 0.5	--	< 0.5	--	< 0.5	--
C6	0.37	--	0.007	--	< 0.5	--
C7	--	1	--	0.6	--	3.6
C8	0.49	--	**5.6**	--	**6.1**	--
C9	--	0.24	**27.4**	0.35	1	0.011
C10	3.1	--	--	--	--	--
CF1	--	0.92	--	**6**	--	**32.8**
CF4	**13**	1.1	**49.3**	**12**	**8.6**	1.9
CF5	--	**21**	--	4.9	--	0.052
CF6	--	0.99	--	**15.2**	--	**13.8**
CF7[a]	--	0.072	--	**6.6**	--	**43.9**
CF9	--	3.8	--	**57.2**	--	**67**
CF10	--	**29.9**	--	**62.4**	--	**22.2**
NT3	**9.2**	--	**5.6**	--	**7.1**	--
NT7	**19.7**	--	**35.5**	**40.6**	**7.9**	--
NT8	5	--	1.7	1.2	**6**	--

Notes:

Numbers presented in bold font exceed the TCLP limit of 5 mg/L.
[a] These locations are not shown in Figure 2 because electrodes at these locations were not used during the demonstration.
-- No sample analyzed from this depth.

Postdemonstration results indicate that 18 out of 35 soil samples exceeded the TCLP regulatory criterion for chromium at concentrations ranging from 6 to 67 mg/L, with a median concentration of 20.4 mg/L.

Removal of Trivalent Chromium

Trivalent chromium concentrations were to be determined by calculating the difference between total and hexavalent chromium concentrations. In general, the ratio of trivalent chromium to total chromium ranged from 7.6 to 94.9 percent in the predemonstration samples and from 27.6 to 99.6 percent in the postdemonstration samples. This large variability precluded the calculation of trivalent chromium concentrations as originally intended because it would have further increased the data variability.

Total chromium concentrations in the 51 predemonstration samples analyzed ranged from 7.7 to 26,800 mg/kg; and total chromium concentrations in the 84 postdemonstration samples ranged from 8.2 to 16,200 mg/kg. Of the 48 locations sampled both before and after the demonstration, 31 locations contained postdemonstration trivalent chromium concentrations that exceeded predemonstration concentrations.

This increase may be the result of chromium migration in the treatment area in addition to inherent variability at the test areas. Therefore, no conclusion was drawn regarding the ISEE system's ability to remove trivalent chromium.

Operating Problems

The ISEE system's operation was observed during the demonstration, and the problems and their resolutions were recorded by SNL personnel. The demonstration lasted over approximately 4,230 hours. The system was not operable for 36 percent of the time. Table 4 presents the reasons for the shut downs and the percentages of shutdown times relative to the entire duration of the demonstration. In addition, the system was not energized for 3 percent of the time (approximately 140 hours) to perform anolyte sampling and soil moisture measurements using the neutron probe.

Comparison to Superfund Feasibility Evaluation Criteria

Table 5 summarizes the ISEE system's performance compared to the Superfund feasibility evaluation criteria. This table is provided to assist Superfund decision-makers in considering the ISEE system for remediation of contaminated soil at hazardous waste sites.

Estimated Treatment Costs

Based on information provided by SNL and the results and experiences gained from the SITE demonstration, an economic analysis was performed to examine 12 separate cost categories for using the ISEE technology to remediate hexavalent chromium-contaminated, unsaturated soils. According to SNL, a full-scale commercial system design would significantly differ from the system operated during the demonstration. In addition, the developer has not completed a full-scale design of a commercial ISEE system. Therefore, it is not possible to prepare a cost estimate for a full-scale ISEE system. Because SNL states that the full-scale treatment system design will be significantly modified based on the performance of the system used during the demonstration, the treatment cost of a full-scale system will also differ from the treatment cost of the system operated during the demonstration. When the technology is ready for commercialization, further economic analysis should be performed.

This cost estimate is based on the system's performance at SNL's preferred operating conditions during test 13 of the SITE demonstration and the following parameters: (1) configuration of four anodes and eight cold finger cathodes, (2) a treatment area of 16 cubic yards, (3) a

Table 4. System Shutdown Information

Reason for System Shutdown	Shut Down Time (percent)
Intentional shutdown to perform maintenance and modifications to the system	21
Problems related to electrode water (such as bladder pumps, float switches, and chiller leakage)	7
Power supply failures and problems	4
pH control system problems	2
Data-logger problems	2
Total	36

Table 5. Superfund Feasibility Evaluation Criteria for the ISEE Technology

Criterion	Discussion
Overall Protection of Human Health and the Environment	• The ISEE technology is expected to protect human health by lowering the concentration of hexavalent chromium in soil under unsaturated conditions. According to the developer, the technology can also treat soil contaminated with other heavy metals under both saturated and unsaturated conditions, but this capability was not evaluated during the SITE demonstration. • Overall reduction of human health risk should be evaluated on a site-specific basis because VOCs could be stripped from soil during treatment and released to ambient air. Also, the system effluent (anolyte) contains hexavalent chromium and therefore needs to be characterized and handled and disposed of as hazardous waste. • The technology protects the environment by curtailing migration of hexavalent chromium in soil. • Protection of the environment at and beyond the point of anolyte extraction depends on how the anolyte is handled and disposed of. Protection of the environment also depends on the extent of VOC emissions.
Compliance with Applicable or Relevant and Appropriate Requirements (ARAR)	• According to the developer, the technology has the potential to comply with existing federal, state, and local ARARs (for example, TCLP limits) for several inorganic contaminants (for example, chromium). However, about 51 percent of the postdemonstration samples did not meet the chromium TCLP limit of 5 mg/L.
Long-Term Effectiveness and Permanence	• Human health risk can be reduced to acceptable levels by treating soil to a 1 x 10^{-6} excess lifetime cancer risk level. The time needed to achieve cleanup goals depends primarily on contaminated soil characteristics. • The treatment achieved is permanent because contaminants are contained in the anolyte, which is extracted from the soil for disposal. • Periodic review of treatment system performance is needed because application of the technology to contaminated soil at hazardous waste sites is new.
Reduction of Toxicity, Mobility, or Volume Through Treatment	• The technology reduces the volume and mobility of contaminants in soil because contaminants are contained in the anolyte, which is extracted from the soil for disposal. • The technology can effectively control soil contaminant migration because contaminants are contained in the anolyte, which is extracted from the soil for disposal.
Short-Term Effectiveness	• About 51 percent of postdemonstration samples did not meet the chromium TCLP limit of 5 mg/L. This failure may be because the developer did not have the state permit required to carry out the demonstration for a longer period of time.
Implementability	• The technology is still in the development stage. No commercial system is currently available from SNL. • State and local permits must be obtained to operate the ISEE system.
Cost	• Treatment costs vary significantly depending on the size of the treatment system used, contaminant characteristics and concentrations, cleanup goals, the volume of contaminated soil to be treated, and the length of treatment. Economic data indicate that soil remediation costs are very high, perhaps because the system demonstrated at UCAP was not of commercial scale and requires significant improvements.
State Acceptance	• This criterion is generally addressed in the record of decision. State acceptance of the technology will likely depend on (1) expected residual contaminant in soil, (2) how the anolyte is handled and disposed of, and (3) the steps taken to reduce the potential for VOC emissions.
Community Acceptance	• This criterion is generally addressed in the record of decision after community responses have been received during the public comment period. Because communities are not expected to be exposed to harmful levels of fugitive emissions, the level of community acceptance of the technology is expected to be moderate.

hexavalent chromium removal rate of 0.29 g/hour, (4) a hexavalent chromium removal efficiency of 0.14 g/kWh, and (5) an on-line time of 85 percent. The total treatment costs for the ISEE system to treat 16 cubic yards of soil are estimated to be $1,400 per cubic yard for removing 200 g of hexavalent chromium. The estimate will vary depending on cleanup goals, soil type, treatment volume, and system design changes. The estimate is order-of-magnitude estimate, as defined by the American Association of Cost Engineers, with an expected accuracy of +50 percent to -30 percent. A detailed explanation of these costs, including the 12 cost categories examined, is presented in the ITER.

Technology Status

The SNL ISEE system is not commercially available for treatment of contaminated soils. The system evaluated during the SITE demonstration is a prototype and not the system that will be used for actual remediation. To conduct actual soil remediation, SNL's research team plans to design and build a system that is low-maintenance and that can be operated unsupervised for a long time. SNL states that the cost of remediation will be significantly reduced as a result of these improvements.

Source of Further Information

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